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STUDY OF THE DISSOCIATION OF MOLECULAR HYDROGEN

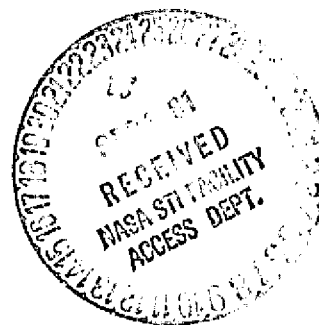
Contract NAS8-33521

Final Report

For the period 2 January 1980 to 30 April 1981

Principal Investigator  
Dr. Robert F.C. Vessot

July 1981



Prepared for  
National Aeronautics and Space Administration  
Marshall Space Flight Center, Alabama 35812

Smithsonian Institution  
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STUDY OF  
THE DISSOCIATION OF MOLECULAR HYDROGEN  
FINAL REPORT

INTRODUCTION

Early in 1980 the Smithsonian Astrophysical Observatory, with support from the National Aeronautics and Space Administration under Contract NAS8-33521, began a program to study various types of r.f. discharge plasma-type dissociator systems for hydrogen masers to be used in long-term applications in space. This report will describe the progress to date and outline directions that the program could take in future investigations.

The chief problem in producing atomic hydrogen efficiently and reliably in laboratory masers has been the deterioration of the wall surfaces in the vessel confining the low pressure r.f. plasma discharge and the reliability of the r.f. power transfer to the ionized gas. The r.f. dissociators in general use for hydrogen masers consist of a cylindrical pyrex glass tube about 3 cm diameter with an inlet for molecular hydrogen and an outlet leading to a collimator to produce a directed beam of atomic hydrogen. Hydrogen flow rates are small, generally no larger than  $10^{15}$  molecules per second. The pressure required to sustain an r.f. plasma discharge roughly depends on the dimensions of the vessel and the choice of frequency of the r.f. excitation which is generally kept higher than, or at least commensurate with, the reciprocal of the mean free time for an electron to traverse the plasma going from one wall to another across the tube. A

theoretical study of the processes in the r.f. hydrogen gas dissociator, recently made at J.P.L.,\* discusses the relationship of pressure, frequency, and dissociator dimensions.

It is clear that by minimizing the rate of electron collisions at the walls, the walls can be spared erosion that can deteriorate their ability to prevent atomic recombination. In addition, it is desirable to reduce or eliminate contamination by elastomer seals which can cause the wall to become catalytic surfaces and recombine atomic hydrogen. We can see several areas where improvements can be made: (1) The nature of the storage vessel walls; (2) the manner in which the plasma is sustained by an external r.f. field; (3) the manner in which heat is removed from the dissociator; and (4) elimination of possible sources of contamination in the dissociator gas inlet connection.

#### THE TEST SYSTEM

Our approach was to build a two-station test system to operate r.f. dissociators and evaluate their performance. One station (Station 2) operates as a test bed to study dissociators of different materials to observe the surface erosion under adverse operating conditions. The other station (Station 1) provides a workplace to test various r.f. configurations. Figure 1 shows the test system as it is now configured and successfully operating.

The two main objectives we expect to achieve with the new dissociators are: (1) to operate the dissociator totally within the vacuum envelope of the maser and thus eliminate all forms of external air cooling, and (2) to eliminate elastomer O rings

\* L. Maleki  
Telecommunications and Data Acquisition Progress Report 42-59,  
July-August 1980, P.68

and other vacuum seals capable of producing contaminants that can accumulate over long periods of operation. There is also a requirement for the dissociator to be self-starting and not require additional adjustment or manipulation once the r.f. power is applied.

The present system has two separate and completely independent hydrogen pressure controls. Station 1 is currently set up to operate a dissociator under conventional conditions in ambient air with no forced air circulation, with a variety of excitation circuits to support an r.f. plasma discharge. It is operating at relatively constant hydrogen flux and also serves as a test bed for various hydrogen scavenging methods.

Currently, the most promising r.f. configuration is a low impedance 3-turn loop structure that generates sufficient r.f. electric field to start the plasma very reliably and maintains the discharge with very little evidence of erosion. An alternate configuration of a coil made in a printed circuit configuration as a 3-turn spiral printed circuit has also proved to be effective and can be very rigidly supported. The chief drawback of a lower impedance one-turn structure is the difficulty in obtaining a high enough voltage to start the dissociator by initiating ionization, and a requirement for somewhat more r.f. power than required by the electric field mode of excitation. We plan to improve starting with an initiator in the form of a minute amount of an alpha particle emitter such as polonium or americium sealed inside the tube. This technique has long been used in the hydrogen plasma tubes of high power radar transmit-receive switches.

Test station 2 (shown to the right in Figure 1) is used to test the performance of r.f. dissociators that are completely vacuum enclosed. This system is pumped by a turbo-molecular vacuum pump (TMP) and is kept well below  $10^{-6}$  torr during tests. It is equipped with r.f. and d.c. feedthrough ports. The glassware now in use is made of Corning 7070 low-loss glass and has been running for 3 months.

Both stations can, by valves, be connected to the TMP, through a manifold that contains a residual gas analyser and a Varian Smart gauge. The former is used to determine the relative abundance of outgassing products; the latter is used as a pressure gauge and with its nitrogen detecting feature, is used to leak check the system during operation.

#### SOME COMMENTS ON HYDROGEN SCAVENGING SYSTEMS

The first use of sorption cartridges in hydrogen masers was made in 1974-1976 during the development of the spaceborne maser for the SAO/NASA Gravitational Redshift experiment. One of the dominant constraints in this program was weight; it was clear from the outset that the conventional large capacity ion pump weighing over 200 pounds and its requirement for large magnetic shields, could not be accommodated by the Scout rocket system used to fly the experiment. Alternative hydrogen scavenging systems using chemisorption were tried and, after considerable testing, a combination of sorption cartridge and low voltage ion pump was adopted.

The sorption cartridge we used was made by SAES Getters Company and consisted of zirconium and aluminum in the form of a powder sintered to the surface of a thin strip of stainless steel pleated back and forth, and confined in a canister like an automobile oil filter. Once activated by heating under vacuum at well over  $700^{\circ}\text{C}$ , this device has an extraordinary appetite for hydrogen at room temperature and to a limited extent, can cope with outgassed oxygen, nitrogen, CO, and  $\text{CO}_2$ . However, hydrocarbons and noble gases were not pumped and we found that by using a very small ion pump operating at low voltage ( $<2\text{kV}$ ), the ion pump would successfully dissociate hydrocarbons and capture the carbon and the noble gases without being glutted by hydrogen, which at low voltage is not effectively pumped by sputtering.

Our tests showed that a single cartridge about 3" diameter by 5" long would operate the maser for one year when operated with a single 0.1 liter/sec. ion pump (about the size of a walnut).

Since that time, SAES has developed new cartridges using a graphite matrix with zirconium and other metals. These are more compact and according to reports, have even more capacity for hydrogen than the older versions.

The chief question remaining is the ability of the new cartridge to cope with non-hydrogenic species like  $\text{N}_2$ ,  $\text{O}_2$ , CO and  $\text{CO}_2$ , normally evolved by metal vacuum systems that are not bakeable at temperatures much beyond  $150^{\circ}\text{C}$



ONGOING TESTS OF HYDROGEN SCAVENGING - JULY 1981

We are now operating Station 1 of the test system using one of the new sorption cartridges and observing hydrogen scavenging capability in the presence of contaminants normally existing in the masers. This test has been running since May 18, 1981 and will continue until the hydrogen partial pressure reaches  $1 \times 10^{-5}$  torr. We will then reactivate the cartridge and determine its outgassing products using the residual gas analyser in the system. The test will be repeated with two or more cartridges to see if they behave consistently.

ONGOING TESTS OF A VACUUM ENCLOSED DISSOCIATOR - APRIL 10 - JULY 1981

A test is now in progress to observe the possible deterioration of a completely vacuum enclosed atomic hydrogen dissociator suitable for use in long-term operation in space. The thermal design of the present dissociator is based on the use of a low dielectric loss borosilicate glass (Corning 7070) with thermal conduction through the top and bottom surfaces to the main mounting flange. Figure 2 shows the design as it would be adapted for use in an actual maser. The dissociator now under test is reasonably close to this design.

Our test procedure first is simply to run this dissociator with various levels of r.f. excitation and measure the temperature rise of the glassware to obtain power dissipation information. This will be repeated using the conventional Corning 7740 glassware to see if there is any benefit in the low loss Corning 7070 glass. The next step is to accelerate the deterioration of the dissociator by operating it at a

substantially higher power level and at twice the normal source pressure and visually observe any noticeable erosion as time progresses.

To date, after about 3 months of operation, the 7070 dissociator is operating flawlessly. The temperature rise vs. power input results are fairly well understood and we have

$$dT/dP \sim 5^{\circ}\text{C/watt}.$$

#### PLANS FOR THE CONTINUATION OF THE STUDY OF ATOMIC HYDROGEN SOURCES

The current effort will proceed as a life testing program. Station 1 will continue to be used for dissociator life testing and Station 2 will be used for the development of a cold hydrogen dissociator, under NASA/MSFC Grant No. NAG-8012.

Data are taken daily to monitor pressures, voltages, temperatures and excitation power levels. We will continue to do this as long as possible in an effort to simulate some of the aspects of long-term operation in space. We are now optimistic that a source of atomic hydrogen can be developed that will operate for at least 5 years in the vacuum of space.

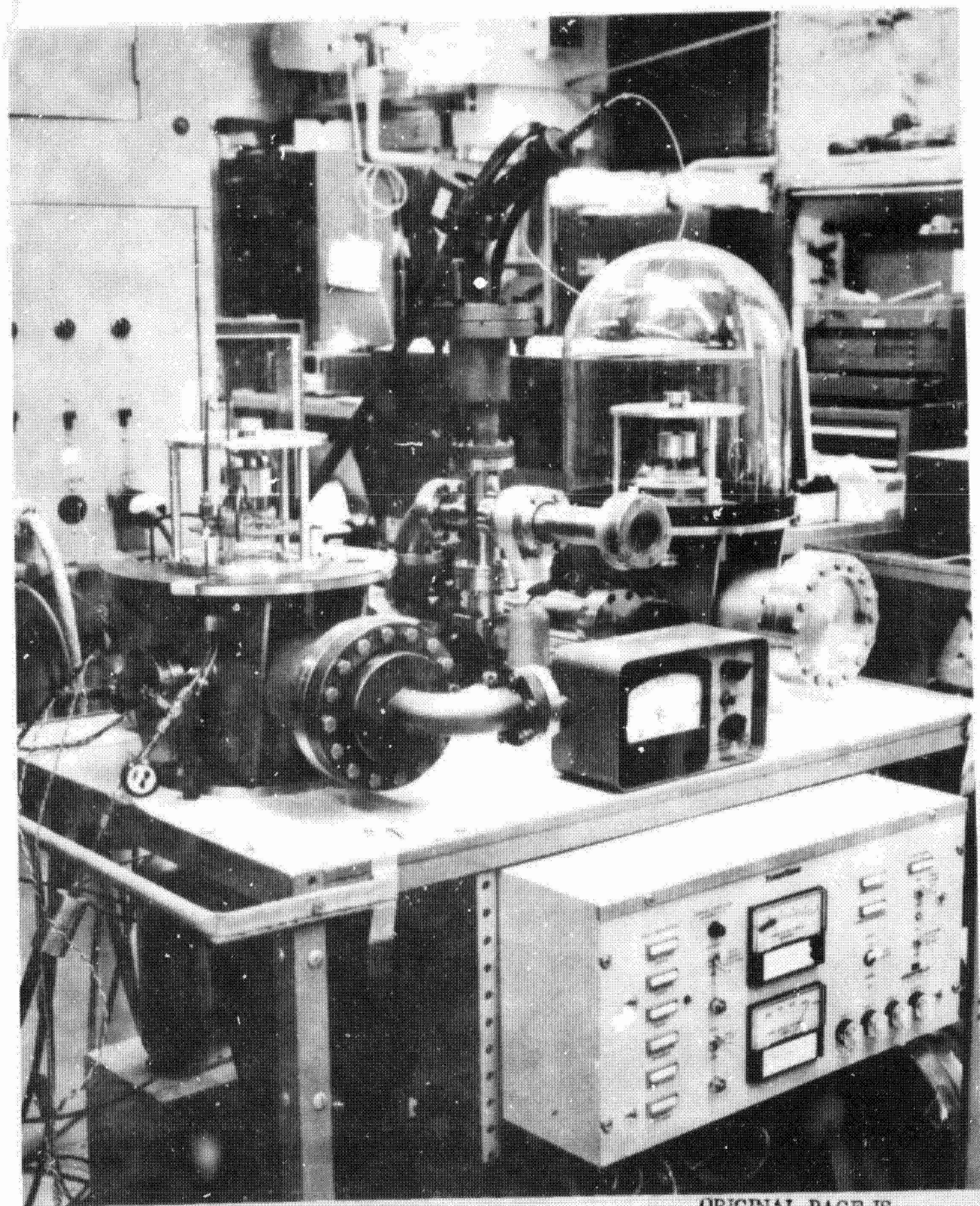


FIG. 1. HYDROGEN DISSOCIATION TEST SYSTEM

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